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Procedia Engineering 113 (2015) 312 – 315
Procedia Engineering
www.elsevier.com/locate/procedia

International Conference on Oil and Gas Engineering, OGE-2015

Expert systems of multivariable predictive control of oil and gas facilities reliability

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Abstract

The authors conducted a set of studies concerning the development of methodological support of multivariate predictive control reliability system for oil and gas industry. The algorithms, the innovative methods of calculation and the mathematical models of reliability factors, compatible with the modern production technological maintenance system, the system of dispatcher data registration, non-destructive testing diagnostics, and automated process control systems are developed. The mathematical software is designed to meet the technological features of the specific facilities, with applying the theory of process analysis, theory of reliability and fluctuation analysis elements. The developed models of reliability factors provide the possibility of predicting the parameters of technical facilities in a real time mode or for a fixed period, the structural and factor analysis function of the system in order to plan its optimal maintenance.

Peer-review under responsibility of the Omsk State Technical University

Keywords: reliability; safety; pipeline transport; reliability prediction

1. Introduction

Monitoring technologies of MPC (multivariable predictive control) meet modern economical, production, and safety requirements based on the special continuous control of quantitative and running values of various factors: controllable, regulated, (set-points) and performance ones [1, 2].

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Peer-review under responsibility of the Omsk State Technical University
doi:10.1016/j.proeng.2015.07.271

For the prediction and assessment of the reliability of pipeline transportation and hydrocarbon storage facilities in real time, complex study of all the factors, phenomena and processes that determine various properties of the system reliability is necessary.

The analysis of existing studies indicates that, despite the urgency of the problem and a significant amount of research, existing techniques allow only a one-time assessment of reliability and are not focused on the use of immediate assessment and prediction in real time with the use of modern computer technologies [3- 6].

2. Study subject

The subject of the study is the technology of reliability prognostic control, which requires the development of algorithmic and mathematical set.

3. Methods

Based on the analysis of the operating experience of the industrial facilities, it seems advisable to divide the sequence of the basic processes of design, implementation, and monitoring systems operation into several stages (Fig. 1). Stages 1, 2, 5, 6, and 7 are based on the results of theoretical and industrial research, while stages 3 and 4 are undertaken by organizations, developing information systems, as well as involved directly in construction and operating of the hazardous facility.

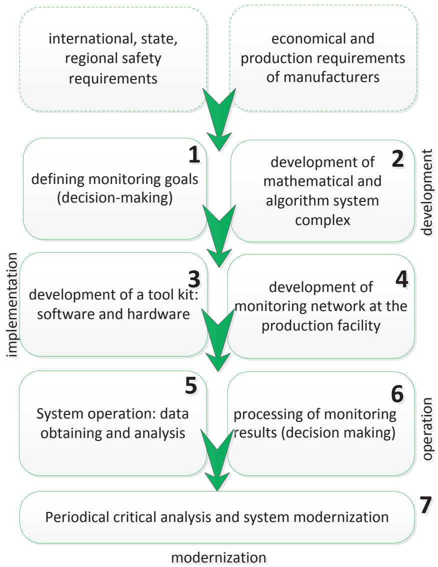

Fig. 1. Algorithm of developing the technological processes monitoring system

It is necessary to note, that possibilities and prospects of the implementation of the developed MPC system are not limited by only technological sphere of production: they are also focused on the scientific research and project institutes, regulatory authorities while evaluating the risk, choosing the complex of technological equipment for diagnostic and planned preventive maintenance, declaring organizations safety and so on.

Almost every system of technological or industrial monitoring and control contains information databank. The system of source data collection is constructed in such a way that can be generated at existing organizations using both current and new hardware.

For the analysis and control the system reliability, are formed structural and factor analysis algorithms, which, on a real-time basis, allow:

- evaluating reliability indices of every system element at any level, and identifying the most vulnerable elements;
- determining system settings, which have the greatest impact on the facility reliability.

It should be noted that the basis for developing a methodology for monitoring the reliability of pipeline transportation facilities systems and sub-systems is a complex of requirements, including the following:

- multivariable models of the system reliability should provide unambiguous, correct operational quantitative assessment of a particular hazardous facility;
- a system model and a set of universal logical-mathematical models should allow to make comprehensive evaluation and analysis of reliability, taking into account the factors and parameters that change in long periods of operation and storage, and constantly changing parameters in real-time modes;
- correlations between factors and indicators (often dependent or not uniquely determined) affecting the safety and reliability of the technical system as a whole (in particular, e.g., retention) should be clearly defined;
- methods for evaluating the reliability of the technological system should be compatible with existing systems technological processes ACS and allow the parameters to be adjusted under the influence of various factors;
- MPC system should provide functions for predicting (using the theory of probability and mathematical statistics) process parameters, planning, optimization and safe and effective control of the technical system as a whole.

That is why the developed monitoring is based on the system analysis method being practically the only one providing decision-making under conditions of a large amount of information of different nature. MPC implements the principle of continuous scanning of reliability factors (in the system, it is a controlled variable CV) and comparing the values obtained with the critical one (Fig. 2). Upon reaching the critical values of the controlled factors, the area and the type of technical intervention is determined.

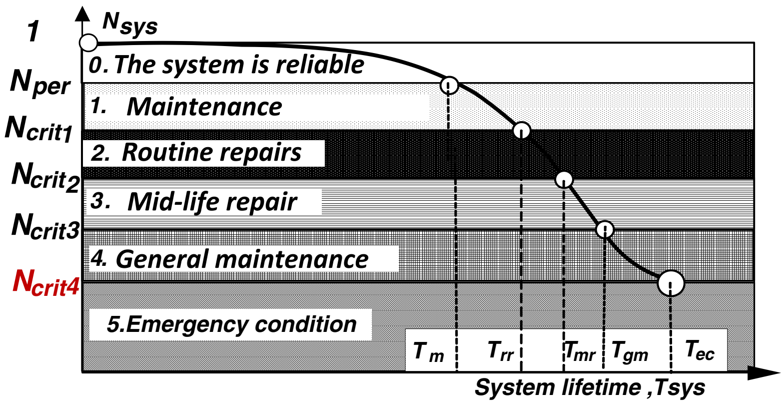

Fig. 2. Schematic diagram of a technical system reliability factor analysis

With the purpose of implementing the estimation and analysis algorithms, we developed a set of mathematical models and calculation methods. Let the example be a methodology, based on the coefficient model of reliability factor.

There are various models for estimating technical facilities reliability: experimental models; “parameter – dimensional limits”; “load – strength”; “load – bearing capacity”; model coefficients.

There is no doubt, that coefficient methods are the most efficient universal methods for the implementation under conditions of long equipment operating period, under uncertainty and lack of information, because they represent a simplified set of complex particular models.

The connection of reliability factors and operating conditions is provided by coefficients, considering the influence on the reliability factors: production technology characteristics; climatic factors; load factors: mechanical, electrical, etc.; facilities complexibility; maintenance characteristics etc.

Thus, the problem formulated above can be solved by using coefficient models in combination with expert assessment of the coefficients significance.

The mathematical model of the monitoring system according to operational factors is based on the following assumptions and correlations:

- system reliability N_{sys} is characterized by a complex of reliability factors S_i, domain of functions

$$N_{\mathrm{sys}} \in [0;1], \quad S_i \in [0;1];$$

- factors S_i, are characterized by changing system operating parameters, i.e.:

$$N_{sys} = f(S_1,\ S_2, S_3 \ldots S_n),\ n \geq 1; \tag{1}$$

$$S_i = f(y_i),\ y_i \in \left[y_{\min}^{per}; y_{\max}^{per}\right] or\ S_i = f(t) \tag{2}$$

General reliability factor is an integral value, found by using the method of linear convolution for every technological system facility considering the hierarchy:

$$N_m = \sum_i^n S_{i_{m-1}} \cdot k_{i_{m-1}} \tag{3}$$

where N_m is function of the system reliability of complexity degree m; S_{im-1} is reliability factor at hierarchy level (m-1) (by structural and factorial scheme); i is factor number $i \in [1;n]$; k_i is significance weight factor for the i -th factor.

Qualitative and quantitative parameters composition S_i (e.g., retention) is determined individually for every system at various hierarchical levels, based on the functional characteristics of the technological scheme of the facility. Values of k_i are calculated by mathematical multivariable models or expert estimates.

4. Results and discussion

The practical importance of the research includes the development of the set of mathematical models and prediction methods for the decision support and reliability factors monitoring system, operating on a real-time basis and providing the transition from the “after-failure” system of maintenance and repair to the preventative one, based on predictive reliability data.

References

[1] V.Kurushina, Y. Zemenkov, Innovative cyclical development of the Russian pipeline system. WIT Transactions on Ecology and the Environment 190, 2 (2014) 881

[2] Y.N Antip'ev, A.P. Nevolin, Yu.D Zemenkov, Operation of intermediate pumping stations on transport of gas saturated oils. NEFT. KHOZ. 10, (1981), pp. 46

[3] V.N Blinov, V.V., Kositsin, V.I. Ruban, V.V. Shalay, The research of ammonia electrothermal microengines for small spacecrafts Dynamics of Systems, Mechanisms and Machines, Dynamics 2014 - Proceedings 7005640.

[4] V. Trushlyakov, V. Shalay, J. Shatrov, M. Jakovlev, A. Kostantino, Active de-orbiting onboard system from LEO of upper stages of launchers, European Space Agency, (Special Publication) ESA SP 672 SP (2009).

[5] A.S. Bacherikov, M.I. Pashkov, Y.V. Bogatenkov, Y.D. Zemenkov, V.V. Shalay, G.G. Vasiliev, A.D. Prokhorov, S.N. Sidelnikov, S.Y. Podorognikov, V.F. Kehl, Y.D. Zemenkov, Ed. Diagnosis in the maintenance of pipeline transportation. St.Peterburg: Nedra, (2007) 380 p.

[6] V.V. Shalay, V.I. Trushlyakov, V.Y. Kudentsov, Simulation of heat and mass transfer processes during gasification of liquid remaining fuel in the tanks missiles, Thermal processes in the art. T. 6. no 2 (2014) 67-74.